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SPECIFICATION

CHANNEL ESTIMATION CIRCUIT AND CHANNEL ESTIMATION METHOD

Technical Field

The present invention relates to a channel estimation circuit and a channel estimation method for implementing channel estimation adaptively in accordance with noise and interference power levels.

Background Art

In conventional channel estimation circuits, improvements of the S/N ratio in channel estimation have been often contemplated wherein a threshold is set and noise paths having a level equal to or lower than the threshold are removed (see Japanese Patent Application Laid-open 2000-261412, for example).

FIG. 1 shows an example of construction of a conventional channel estimation circuit.

As shown in FIG. 1, channel estimation circuit 401 of this conventional example includes, tentative channel estimation unit 102, threshold decision unit 404, and effective path detection unit 105.

Tentative channel estimation unit 102 is supplied with received signal S_r and performs channel estimation by making use of a pilot signal contained in received signal S_r and outputs the result of estimation as tentative channel estimation signal S_{tcest}.

Threshold decision unit 404 establishes and outputs threshold signal S_{th}.

Effective path detection unit 105 is supplied with tentative channel estimation signal S_{tcest} and threshold signal S_{th} and, after removing noise paths having powers smaller than threshold signal S_{th} among paths of the tentative channel estimation signal S_{tcest}, outputs the remaining signal as channel estimation signal S_{cest}.

However, the conventional channel estimation circuit shown in FIG. 1 suffers from a problem that the advantage of the removal of noise paths by making use of a threshold cannot be sufficiently obtained in a transmission environment in which noise and interference power levels greatly vary.

Disclosure of the Invention

It is therefore an object of the present invention to provide a channel estimation circuit and a channel estimation method that adaptively remove noise paths in accordance with noise and interference power levels, to thereby achieve high-precision channel estimation in a transmission environment in which noise and interference power levels greatly vary,.

A channel estimation circuit of the present invention includes: a tentative channel estimation means for being input with a received signal and performing channel estimation by making use of the received signal and outputting the result of estimation as a tentative channel estimation signal;a noise/interference power estimation means for being input with signals, including at least, the received signal, among the received signal, the tentative channel estimation signal and a channel estimation signal, and performing estimation of noise and interference power by making use of the input signals, to output the result of estimation as a noise/interference power estimation signal; a threshold decision means for being input with signals,

including at least, the noise/interference power estimation signal, among the noise/interference power estimation signal and the tentative channel estimation signal, and establishing and outputting a threshold signal by making use of the input signals; and an effective path detection means for being input with the tentative channel estimation signal and the threshold signal and, after removing noise paths having powers smaller than threshold signal among paths of the tentative channel estimation signal, and outputting the remaining signal as the channel estimation signal.

A channel estimation method of the present invention includes: a step at which a tentative channel estimation means being input with a received signal and performs channel estimation by making use of the received signal and outputs the result of estimation as a tentative channel estimation signal; a step at which a noise/interference power estimation means being input with signals, including at least, the received signal, among the received signal, the tentative channel estimation signal and a channel estimation signal, and performs estimation of noise and interference power by making use of the input signals, to output the result of estimation as a noise/interference power estimation signal; a step at which a threshold decision means being input with signals, including at least, the noise/interference power estimation signal, among the noise/interference power estimation signal and the tentative channel estimation signal, to establish and output a threshold signal by making use of the input signals; and a step at which an effective path detection means being input with the tentative channel estimation signal and the threshold signal and, after removing noise paths having powers smaller than threshold signal among paths of the tentative channel estimation signal, outputs the remaining signal as the channel estimation signal.

As described above, since a threshold is determined based on the estimation values of noise and interference power and removal of noise paths is performed based on that threshold, the present invention enables high-precision channel estimation even in a transmission environment in which noise and interference power levels vary greatly.

Brief Description of the Drawings

FIG. 1 is a block diagram showing an example of construction of a conventional channel estimation circuit.

FIG. 2 is a block diagram showing a configuration of a channel estimation circuit in accordance with the first embodiment of the present invention.

FIG. 3 is a block diagram showing a configuration of a channel estimation circuit in accordance with the second embodiment of the present invention.

FIG. 4 is a block diagram showing a configuration of a channel estimation circuit in accordance with the third embodiment of the present invention.

Best Mode for Carrying Out the Invention

Preferred embodiments of the present invention will be described hereinbelow in detail with reference to the drawings.

(The first embodiment)

FIG. 2 shows a configuration of a channel estimation circuit in accordance with the first embodiment of the present invention. In FIG. 2, the same components as in FIG. 1 are assigned the same reference

numerals.

As shown in FIG. 2, channel estimation circuit 101 according to the first embodiment of the present invention includes tentative channel estimation unit 102, noise/interference power estimation unit 103, threshold decision unit 104 and effective path detection unit 105.

Tentative channel estimation unit 102 is supplied with received signal S_r and performs channel estimation by making use of a pilot signal contained in received signal S_r and outputs the result of estimation as tentative channel estimation signal S_{tcest}.

Noise/interference power estimation unit 103 is supplied with received signal S_r, estimates noise and interference power by making use of received signal S_r, and then output the result of estimation as noise/interference power estimation signal S_{niest}.

Threshold decision unit 104 is supplied with noise/interference power estimation signal S_{niest} and, after having multiplied the noise/interference power estimation signal S_{niest} by an arbitrary constant, outputs the signal as threshold signal S_{th}.

Effective path detection unit 105 is supplied with tentative channel estimation signal S_{tcest} and threshold signal S_{th} and, after removing noise paths having powers smaller than threshold signal S_{th} among paths of the tentative channel estimation signal S_{tcest}, outputs the remaining signal as channel estimation signal S_{cest}.

It is to be noted that, for instance, when CDMA (Code Division Multiple Access) is used for wireless transmission, as a method of estimating noise and interference power in noise/interference power, estimation unit 103 can employ a method of despreading received signal S_r by making use of a

spread code that is not used for wireless transmission so as to cancel out the signal component, to thereby extract noise and interference components alone.

As described above, in the present embodiment, the threshold for removal of noise paths is determined adaptively in accordance with noise and interference power levels. This makes it possible to attain high-precision channel estimation even in a transmission environment in which noise and interference power levels vary greatly.

(The second embodiment)

FIG. 3 shows a configuration of a channel estimation circuit in accordance with the second embodiment of the present invention. In FIG. 3, the same components as in FIG. 2 are assigned with the same reference numerals.

As shown in FIG. 3, channel estimation circuit 201 according to the second embodiment of the present invention includes tentative channel estimation unit 102, noise/interference power estimation unit 203, threshold decision unit 104 and effective path detection unit 105.

Tentative channel estimation unit 102 is supplied with received signal S_r and performs channel estimation by making use of a pilot signal contained in received signal S_r and outputs the result of estimation as tentative channel estimation signal S_{tcest}.

Noise/interference power estimation unit 203 is supplied with received signal S_r and tentative channel estimation signal S_{tcest}, and estimates noise and interference power by making use of received signal S_r and tentative channel estimation signal S_{tcest}, and then output the result of estimation as noise/interference power estimation signal S_{niest}.

Threshold decision unit 104 is supplied with noise/interference power estimation signal S_{niest} and, after having multiplied the noise/interference power estimation signal S_{niest} by an arbitrary constant, outputs the signal as threshold signal S_{th}.

Effective path detection unit 105 is supplied with tentative channel estimation signal S_{tcest} and threshold signal S_{th} and, after removing noise paths having powers smaller than threshold signal S_{th} among paths of the tentative channel estimation signal S_{tcest}, outputs the remaining signal as channel estimation signal S_{cest}.

It is to be noted that, for instance, when CDMA is used for wireless transmission, noise/interference power estimation unit 203 can employ a method of determining the variance of received signal S_r relative to tentative channel estimation signal S_{tcest}, as a method of estimating noise and interference power.

As described above, in the present embodiment, the threshold for removal of noise paths is determined adaptively in accordance with noise and interference power levels. This makes it possible to attain high-precision channel estimation even in a transmission environment in which noise and interference power levels vary greatly.

Further, in the present embodiment, noise and interference power are estimated by a method such as determining the variance of received signal S_r relative to tentative channel estimation signal S_{tcest}. This enables more accurate estimation of noise and interference power. In this case, however, the degradation in the accuracy of estimation of tentative channel estimation signal S_{tcest} also results in the degradation in the accuracy of estimation of noise and interference power.

(The third embodiment)

FIG. 4 shows a configuration of a channel estimation circuit in accordance with the third embodiment of the present invention. In FIG. 4, the same components as in FIG. 2 are assigned with the same reference numerals.

As shown in FIG. 3, channel estimation circuit 301 according to the third embodiment of the present invention includes tentative channel estimation unit 102, noise/interference power estimation unit 303, threshold decision unit 104 and effective path detection unit 105.

Tentative channel estimation unit 102 is supplied with received signal S_r and performs channel estimation by making use of a pilot signal contained in received signal S_r and outputs the result of estimation as tentative channel estimation signal S_{tcest}.

Noise/interference power estimation unit 303 is supplied with received signal S_r, tentative channel estimation signal S_{tcest} and channel estimation signal S_{cest}, estimates noise and interference power, and then output the result of estimation as noise/interference power estimation signal S_{niest}.

Threshold decision unit 104 is supplied with noise/interference power estimation signal S_{niest} and, after having multiplied the noise/interference power estimation signal S_{niest} by an arbitrary constant, outputs the signal as threshold signal S_{th}.

Effective path detection unit 105 is supplied with tentative channel estimation signal S_{tcest} and threshold signal S_{th} and, after removing noise paths having powers smaller than threshold signal S_{th} among paths of the tentative channel estimation signal S_{tcest}, outputs the remaining signal as channel estimation signal S_{cest}.

It is to be noted that, upon the first estimation of noise and interference power, i.e., prior to the input of channel estimation signal S_{cest}, noise/interference power estimation unit 303 implements estimation of noise and interference power, by making use of received signal S_r and tentative channel estimation signal S_{tcest}. In this case, noise/interference power estimation unit 303 can employ, for example a method of determining the variance of received signal S_r relative to tentative channel estimation signal S_{tcest}, as a method of estimating of noise and interference power.

On the other hand, after the channel estimation values, that have been obtained by removal of noise paths by making use of the threshold established based on the first estimation values of noise and interference power, are input as channel estimation signal S_{cest}, noise/interference power estimation unit 303 performs estimation of noise and interference power by making use of received signal S_r and channel estimation signal S_{cest}. In this case, noise/interference power estimation unit 303 can employ, for example a method of determining the variance of received signal S_r relative to channel estimation signal S_{cest}, as a method of estimating of noise and interference power.

As described above, in the present embodiment, the threshold for removal of noise paths is determined adaptively in accordance with noise and interference power levels. This makes it possible to attain high-precision channel estimation even in a transmission environment in which noise and interference power levels vary greatly.

Further, in the present embodiment, at the first estimation of noise and interference power, noise and interference power are estimated by a method such as determining the variance of received signal S_r relative to

tentative channel estimation signal S_{tcest}, whereas, after channel estimation signal S_{cest} has been determined for the channel estimation values that have been obtained by removal of noise paths by making use of the threshold established based on the first estimation values of noise and interference power, noise and interference power are re-estimated by a method such as determining the variance of received signal S_r relative to channel estimation signal S_{cest}. This enables a more accurate estimation of noise and interference power. The procedure to remove noise paths repeatedly by making use of more accurate estimation values of noise and interference power is also possible.

(The fourth embodiment)

Although, in the above first to third embodiments, threshold decision unit 104 is supplied with noise/interference power estimation signal S_{niest} and establishes threshold signal S_{th} by making use of noise/interference power estimation signal S_{niest}, the present invention should not be limited to thereto. Threshold decision unit 104 may be constructed such that it will input not only noise/interference power estimation signal S_{niest} but also tentative channel estimation signal S_{tcest} and establish threshold signal S_{th} by making use of noise/interference power estimation signal S_{niest} and tentative channel estimation signal S_{tcest}.

With this configuration, threshold decision unit 104 may employ, for example, the following first and second methods as a method of establishing of threshold signal S_{th}.

In the first method, threshold decision unit 104 initially sets the signal as threshold signal S_{th} after having multiplied the noise/interference power estimation signal S_{niest} by an arbitrary constant, at first. Next, threshold

decision unit 104 subtracts x, x being an arbitrary real number, from the maximum path power, which is the power of the path having the maximum power among the paths of tentative channel estimation signal S_{tcest}. Then, when the value, that is, the maximum path power minus x, is greater than the initially set threshold signal S_{th}, threshold decision unit 104 outputs the initially set threshold signal S_{th}, and when the maximum path power minus x is equal to or smaller than the initially set threshold signal S_{th}, threshold decision unit 104 outputs the maximum path power minus x as threshold signal S_{th}.

In the second method, threshold decision unit 104 initially sets the signal as threshold signal S_{th} after having multiplied the noise/interference power estimation signal S_{niest} by an arbitrary constant, at first. Next, threshold decision unit 104 calculates, as a total effective power, the sum of the powers of the paths having powers which are equal to or greater than threshold signal S_{th} among paths of tentative channel estimation signal S_{tcest}. Then, when the total effective power is equal to or greater than y, y being an arbitrary real number, threshold decision unit 104 outputs the initially set threshold signal S_{th}, and when the total effective power is smaller than y, threshold decision unit 104 lowers threshold signal S_{th} until the total effective power becomes equal to greater than y, and then outputs that threshold signal S_{th}.